CIRCULAR No. 253 JANUARY, 1933
UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

SPOILAGE OF STONE FRUITS ON THE MARKET

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MARKET LOSSES

Spoilage of fruit on the market results in heavy losses in labor and money with little or no possibility of compensation. Spoilage in the orchard at picking time involves only the cost of growing the crop, whereas a loss on the market adds to this the cost of picking, packing, and shipping. A smaller crop often results in an increased price, but spoilage of part of a shipment is likely to ruin the market for the sound fruit as well as for that diseased. Neither dealers nor consumers care to take a chance on fruit that already shows signs of spoilage and unfortunately the quantity of such fruit that appears on the market is surprisingly large.

Probably the best available picture of the condition of fruit at receiving points is that obtained from the car-lot inspection certificates of the Bureau of Agricultural Economics. A study of these certificates for stone fruits in the years 1922 to 1928, inclusive, shows the spoilage in transit to be largely caused by decay in the form of brown rot [1] and Rhizopus rot. In a total of 7,846 cars of peaches inspected during the seven years, 2,245 cars had 5 per cent or more of the fruit affected with brown rot and 670 cars had 5 per cent or more of the fruit affected with Rhizopus or other form of soft rot.[2]

During the period reported there arrived in the larger markets 766 shipments of peaches in which 20 per cent or more of the fruit was affected with either brown or Rhizopus rot, 987 shipments in which 10 to 20 per cent of the fruit was similarly affected, 1,162 shipments in which 5 to 10 per cent was affected, and 2,504 shipments in which 1 to 5 per cent was affected. (Table 1.)

[1] Brown rot is caused by the fungus *Sclerotinia fructicola* (Wint.) Rehm.
[2] Including a few reports of Penicillium rot, especially on shipments from the Pacific Coast States, and occasional mention of Botrytis and Fusarium.

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Table 1.—*Decay of peaches as shown by car-lot inspection at receiving points*

[Records obtained from inspection certificates, Bureau of Agricultural Economics]

Item	Car lots in—							
	1922	1923	1924	1925	1926	1927	1928	Total
Number of shipments	38,405	33,525	39,497	40,858	58,465	41,714	57,706	310,170
Number of shipments inspected	1,113	817	871	752	1,692	1,202	1,399	7,846
Cars showing decay:								
20 per cent or more of brown rot	165	55	40	9	81	139	117	606
20 per cent or more of Rhizopus rot	20	17	19	13	32	27	32	160
Total	185	72	59	22	113	166	149	766
15 to 20 per cent of brown rot	60	28	24	10	41	78	62	303
15 to 20 per cent of Rhizopus rot	13	7	8	6	30	9	7	80
Total	73	35	32	16	71	87	69	383
10 to 15 per cent of brown rot	73	35	35	18	78	104	120	463
10 to 15 per cent of Rhizopus rot	13	23	31	10	39	9	16	141
Total	86	58	66	28	117	113	136	604
5 to 10 per cent of brown rot	103	81	75	52	153	187	222	873
5 to 10 per cent of Rhizopus rot	32	28	32	42	91	23	41	289
Total	135	109	107	94	244	210	263	1,162
1 to 5 per cent of brown rot	226	201	133	112	324	302	398	1,696
1 to 5 per cent of Rhizopus rot [1]	135	76	102	132	227	75	61	808
Total	361	277	235	244	551	377	459	2,504
15 per cent or more of rot	258	107	91	38	184	253	218	1,149
10 per cent or more of rot	344	165	157	66	301	366	354	1,753
5 per cent or more of rot	479	274	264	160	545	576	617	2,915

[1] In a few instances including some blue-mold rot (Penicillium) and other forms of soft rot.

Shipments containing 20 per cent or more of decayed fruit have little value on the market and are liable to be dumped by order of a board of health. Shipments in which 10 to 20 per cent of the fruit is affected with rot are likely to be disposed of at half price or less, and those in which there is 5 to 10 per cent of rot are almost certain to be sold at a greatly reduced price. Even 1 or 2 per cent of rot is likely to put the fruit at a decided disadvantage in comparison with sound fruit on the same market.

With peaches selling at an average price of about $1,000 a car, and with an average of more than 100 cars a year practically worthless because of decay, about 140 cars a year that must be sold at about half price, and 200 to 400 additional cars that must be sold at a reduced price, there is an annual peach loss on the market of some $200,000 that can be laid to the common forms of decay.

These figures, however, cover only the 7,846 cars actually inspected during the seven years and are therefore based on less than 3 per cent of the annual car-lot shipments. (Table 1.) It is not to be expected that the remaining 97 per cent of the shipments arrived at destination in as bad condition as those inspected, but even the most conservative estimate readily indicates that the total market loss from common forms of peach decay runs into an enormous sum.

SEASONAL EFFECTS

The market loss on peaches is much greater in some years than in others. A number of factors may be partly responsible for this difference, and among these prevailing weather conditions are undoubtedly of great importance.

Comparing the Georgia shipments in 1925 and in 1928 gives a rather extreme illustration of the effect of rainfall upon the prevalence of brown rot at the receiving point. At Macon, Ga., in 1925, from June 15 to August 15, inclusive, 0.01 inch or more of precipitation occurred on each of 16 days, and the total rainfall for the period was 3.66 inches. During the same period in 1928 there were 28 days in which 0.01 inch or more of precipitation occurred and the total rainfall was 23.30 inches.[3] Thus, in 1928 there were nearly twice as many days with rain as in 1925, and the total precipitation was more than six times as great.

In 1925 Georgia shipped 13,513 cars of peaches, and there were 188 calls for inspection, with 4 cars showing 10 per cent or more, and 10 cars showing 5 to 10 per cent of brown rot. In 1928 Georgia shipped 15,926 cars of peaches, and there were 612 calls for inspection, with 176 cars showing 10 per cent or more and 141 cars showing 5 to 10 per cent of brown rot. With only a slight increase in car loadings in 1928 as compared with 1925, there were more than 3 times as many calls for inspections and more than 20 times as much decay on the fruit.

The correlation between rainfall and the occurrence of brown rot seems unquestionable and is generally recognized.

No such relationship was found between weather conditions and the prevalence of Rhizopus rot. In fact, in spite of somewhat fewer car loadings in 1925 than in 1928 and a greatly reduced number of inspections, there were actually more Georgia cars showing 1 per cent or more of Rhizopus rot in 1925 than in 1928.

A study of Table 1 shows that for the country as a whole the number of inspected cars showing brown rot was more than four times as great in 1928 as in 1925, whereas nearly a third more inspected cars showed Rhizopus rot in 1925 than in 1928.

The occurrence of Rhizopus rot in transit is determined almost entirely by picking, packing, and shipping conditions, and the prevailing weather is usually a negligible factor. (P. 5.)

EFFECT OF SPRAYING[4] ON CARRYING QUALITY

The development of rots in transit and on the market is partly determined by the spray program and spraying efficiency of the orchardist. Unsprayed fruit that is apparently sound does not have the same carrying quality as similar fruit that has been properly sprayed. Fruit that has been sprayed a short time before picking is likely to carry better than that which received only the early applications.

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[3] U. S. Weather Bureau records.

[4] As used here, the term "spraying" includes dusting.

SWEET CHERRIES

In the years 1915 to 1919, inclusive, holding and shipping tests were made with several different varieties of sweet cherries from Salem, Oreg.[5] The seasons were not favorable for rot development, and at the time of picking there was practically no rot on either the sprayed or the unsprayed fruit. Shipments of sound fruit were made to Wenatchee, Wash., and to Washington, D. C., and after one to two weeks in the laboratory or in "pony" refrigerators there was shown a decided response to the spray treatment the fruit had received in the orchard.

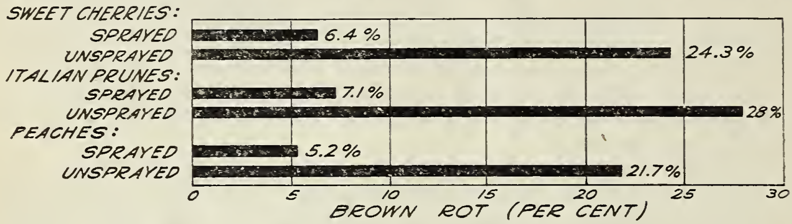

FIGURE 1.—After-harvest development of brown rot on sprayed and unsprayed fruit. The results with cherries (Napoleon, Lambert, and Republican) are the average from 18 different shipping and holding experiments; those with plums (Agen and Italian Prune), the average of 11 different shipping and storage tests; and those with peaches (Hiley, Yellow Hiley, and Elberta), the average results in 11 different shipments in standard refrigerator cars

In 18 different shipping and holding tests the sprayed cherries showed an average of only 6.4 per cent, and the unsprayed cherries an average of 24.3 per cent, of brown rot. (Fig. 1.) Fruit that had received the last spray application (three to four weeks before harvest) showed less than half as much rot as fruit that did not receive this application. (Fig. 2.)

PLUMS (AGEN AND ITALIAN PRUNE)

In the years 1915 to 1918, inclusive, holding and shipping experiments were made with plums of the Italian Prune variety from Felida, Wash.,

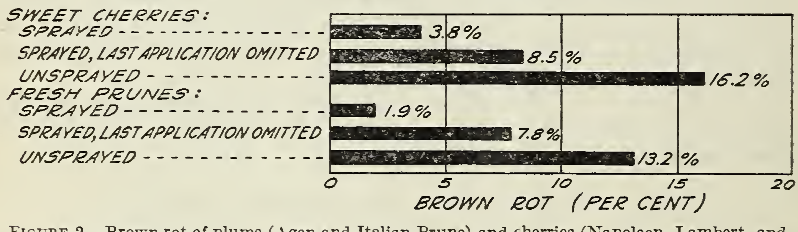

FIGURE 2.—Brown rot of plums (Agen and Italian Prune) and cherries (Napoleon, Lambert, and Republican) as influenced by a late spray application (three to five weeks before picking). The results with cherries are the average from 15 different shipping tests, and those with plums the average from 11 shipping tests

and in 1919 with Italian Prunes and Agen (French) prunes from Salem, Oreg.[6] At picking time there was an average of 4.6 per cent of brown rot on the unsprayed fruit and 1.6 per cent on the sprayed fruit. After storage or shipment of the sound fruit the results of 11 different tests gave an average of 28 per cent of brown rot on the unsprayed prunes and 7.1 per cent on the sprayed prunes. (Fig. 1.) About one-half of this effect upon the carrying quality of the fruit was due to the last spray application (three to five weeks before picking). (Fig. 2.)

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[5] BROOKS, C., and FISHER, D. F. TRANSPORTATION ROTS OF STONE FRUITS AS INFLUENCED BY ORCHARD SPRAYING. Jour. Agr. Research 22:467-477, illus. 1921.

[6] See footnote 5.

PEACHES [7]

In the years 1921 to 1924, inclusive, Georgia peaches from sprayed and unsprayed plots were forwarded to eastern markets in standard refrigerator cars. The results from 11 such shipments of apparently sound fruit are shown in Table 2. Upon arrival at destination an average of 21.7 per cent of the unsprayed fruit was affected with brown rot, as compared with 5.2 per cent of the sprayed fruit affected.

TABLE 2.—*Brown rot at destination: Sprayed compared with unsprayed peaches*

Variety	Year	Percentage of peaches affected with brown rot at time of unloading		Variety	Year	Percentage of peaches affected with brown rot at time of unloading	
		Sprayed	Unsprayed			Sprayed	Unsprayed
Hiley	1921	5.8	8.2	Hiley	1924	3.5	14.2
Elberta	1921	16.3	65.5	Do	1924	5.0	31.3
Yellow Hiley	1922	9.6	23.0	Elberta	1924	1.0	10.6
Do	1922	3.4	19.5	Do	1924	1.3	27.7
Do	1923	9.1	22.1				
Do	1923	1.1	14.7	Average		5.2	21.7
Elberta	1923	.7	1.9				

IMPORTANCE OF CARE IN HANDLING

The importance of careful handling of fruits of all kinds has been repeatedly pointed out in the publications of the State experiment stations and of the United States Department of Agriculture. Many rot organisms can not gain entrance through the unbroken skin of the fruit, and even the most completely parasitic ones are greatly aided by skin punctures. Injury to the skin may occur through carelessness in picking, hauling, grading, or packing, and may be the result of bruises, scratches, finger-nail punctures, skin breaks at the stem, or other forms of injury.

In the plum and cherry experiments reported above it was found that sprayed fruit developed practically as many Rhizopus and blue-mold rots as the unsprayed fruit and that these rots usually if not always started at points of injury. In the peach shipments it was found that sound fruit could actually be dusted with the spores of Rhizopus without developing rot, and that brown-rot infection was greatly decreased and also delayed if there were no visible breaks in the skin.

EFFECT OF TEMPERATURE

Timely spraying decreases the number of fungus spores available to inoculate the fruit, and careful handling reduces the probability of their gaining entrance to the fruit; but the queston whether rots will have time to develop during the usual marketing period is determined almost entirely by temperature. Low temperatures not only delay the rots but also reduce their number.

In considering either the time required for brown rot to become evident on peaches or the number of rots that will be produced, 1 day at 75° F. is practically equivalent to 3 days at 50°, 7 days at 41°, or

[7] BROOKS, C., and COOLEY, J. S. TIME-TEMPERATURE RELATIONS IN DIFFERENT TYPES OF PEACH-ROT INFECTION. Jour. Agr. Research 37: 507–543, illus. 1928.

25 days at 32°.[8] A temperature of 90° or above is unfavorable for the development of brown rot.[9]

Rhizopus rot makes as good a start in 1 day at 85° F. as in 3 days at 59° or in 10 days at 50°, and the lower temperatures have a much

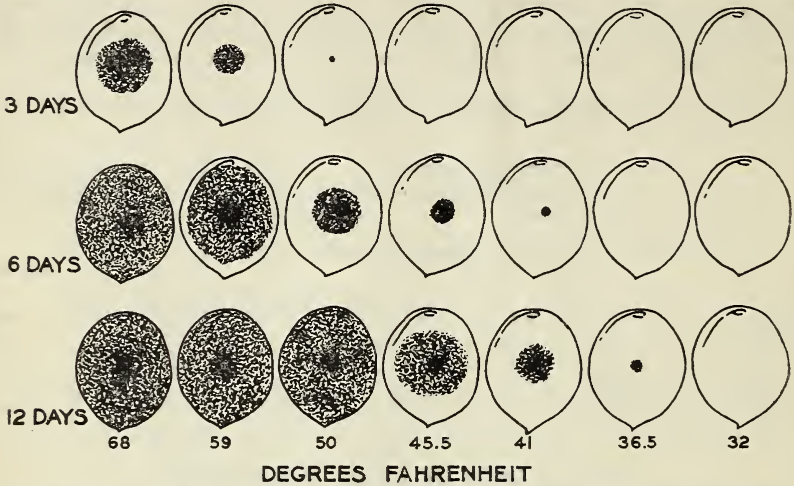

FIGURE 3.—Effect of temperature on development of brown rot on peaches. Average of results from a large number of experiments. Shaded areas indicate extent of decay. The upper series shows the size of the rots at the various temperatures after 3 days, the second series after 6 days, and third series after 12 days

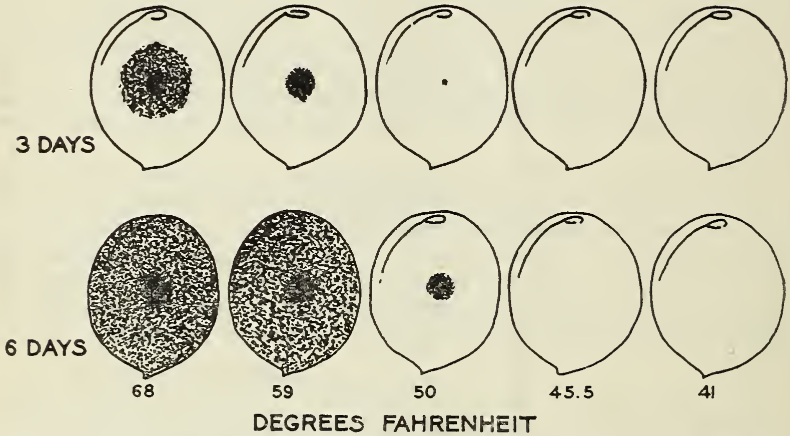

FIGURE 4.—Effect of temperature on development of Rhizopus rot on peaches. Average of results from a large number of experiments. Shaded areas indicate extent of decay. The upper series shows the size of the rots at the various temperatures after 3 days and the second series after 6 days

greater inhibiting effect upon the number of rots than they do upon the rate of growth. At 50° Rhizopus is seldom able to make a start on stone fruits.[8]

The effects of different temperatures upon brown rot and Rhizopus rot of peaches are shown graphically in Figures 3 and 4.[10]

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[8] See footnote 7.

[9] BROOKS, C., and COOLEY, J. S. TEMPERATURE RELATIONS OF STONE FRUIT FUNGI. Jour. Agr. Research 22:451–465, illus. 1921.

[10] Figs. 3 and 4 are from the publication referred to in footnote 9.

COMPARATIVE AMOUNTS OF DECAY IN DIFFERENT LAYERS IN THE CARLOAD

INSPECTION RECORDS

In some of the inspections reported in Table 1, separate records were made for the different layers of packages in the car. The contrasts in amounts of brown rot in the different layers are shown in Table 3 and the contrasts in amounts of Rhizopus rot in Table 4.

TABLE 3.—*Brown rot of peaches in different layers of crates or baskets in cars as shown by inspection certificates of the Bureau of Agricultural Economics*

CRATES

Year	Number of cars	Average percentage of brown rot			
		First (bottom) layer	Second layer	Third layer	Fourth (top) layer
1922	142	4.3	7.3	17.2	24.0
1923	160	1.8	2.6	7.4	15.1
1924	39	2.7	3.6	8.2	17.6
1925	7	1.4	1.4	7.6	14.1
1926	44	.4	1.3	5.0	12.6
1927	51	1.0	2.0	6.9	15.4
1928	35	.5	1.1	6.7	18.2
Total cars and average percentage of rot, 1922–1928	478	2.3	3.8	10.0	18.0

BASKETS

Year	Number of cars	First (bottom) layer	Second layer	Third layer	Fourth (top) layer
1922	207	3.3	7.7	16.6	----------
1923	117	2.6	6.1	13.7	----------
1924	111	3.2	5.1	11.7	----------
1925	30	3.2	5.5	11.2	----------
1926	259	3.6	9.6	17.6	----------
1927	291	3.5	8.6	17.7	----------
1928	416	3.5	8.4	16.8	----------
Total cars and average percentage of rot, 1922–1928	1,431	3.4	8.1	16.3	----------

TABLE 4.—*Rhizopus rot of peaches in different layers of crates or baskets in cars as shown by inspection certificates of the Bureau of Agricultural Economics*

CRATES

Year	Number of cars	Average percentage of Rhizopus rot			
		First (bottom) layer	Second layer	Third layer	Fourth (top) layer
1922	41	1.0	2.2	7.0	14.0
1923	13	.2	.2	3.7	12.1
1924	8	1.2	1.3	13.8	21.9
1925	15	.3	.6	1.4	6.9
1926	48	.9	1.4	4.5	11.8
1927	7	.0	.9	1.1	8.9
1928	4	2.5	2.5	13.0	19.8
Total cars and average percentage of rot, 1922–1928	136	.8	1.4	5.5	12.5

BASKETS

Year	Number of cars	First (bottom) layer	Second layer	Third layer	Fourth (top) layer
1922	146	1.4	2.5	4.9	----------
1923	30	1.5	2.1	7.9	----------
1924	66	2.3	5.2	13.2	----------
1925	46	1.5	3.3	8.5	----------
1926	173	1.5	4.3	10.2	----------
1927	9	1.7	5.3	9.9	----------
1928	65	3.3	11.1	17.5	----------
Total cars and average percentage of rot, 1922–1928	535	1.8	4.5	9.7	----------

In the cars loaded with crates there was an average of 4.3 times as much brown rot and 6.9 times as much Rhizopus rot in the third layer as in the first, and 7.8 times as much brown rot and 15.6 times as much Rhizopus rot in the fourth layer as in the first. In the cars loaded with baskets there were 4.8 times as much brown rot and 5.4 times as much Rhizopus rot in the third layer as in the first.

If the layers were to be sold separately, the differences in market value would be much greater than the differences in percentage of decay. If the peaches were sold on a market where the 1 to 4 per cent of decay in the bottom layers would result in 5 per cent discount in price, it is likely that the 10 to 20 per cent of decay in the top layers would result in a price discount of at least 50 per cent.

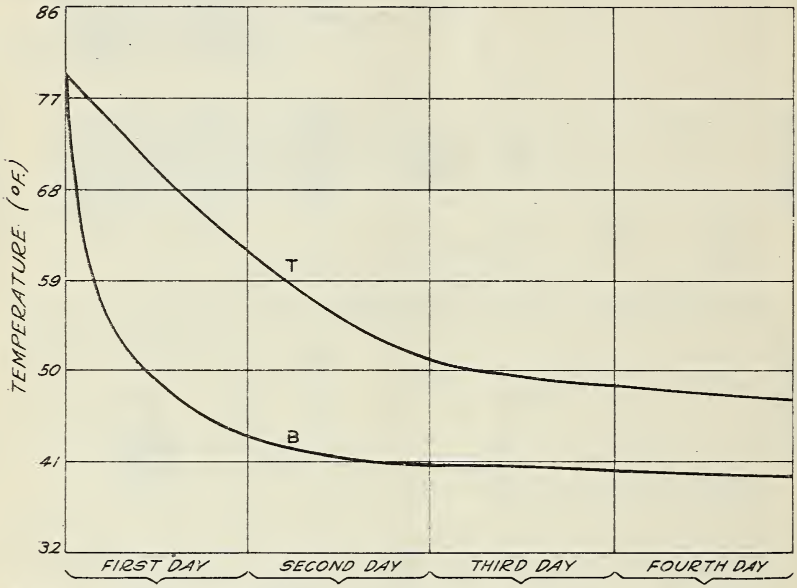

FIGURE 5.—Average of temperature records in standard refrigerator cars for 10 shipments of peaches, 1921 to 1926: T, Top of load; B, bottom of load; both records taken halfway between bunker and doorway. The cars were loaded four crates high.

The data clearly show that fruit of uniform quality at the shipping point may not be of uniform quality at the destination even when loaded in the same car. These differences in amount of decay between the top and the bottom of the load at destination are due to differences in temperature in transit. This is shown in the résumé of experimental results that follows.

RESULTS OF TEST SHIPMENTS

Temperature conditions for peaches loaded four crates high in standard refrigerator cars are shown in Figures 5 and 6. Figure 5 shows the average of the temperature records in 10 carloads of Georgia peaches shipped in 1921 to 1926, inclusive, and Figure 6 shows a similar average for 5 carloads shipped in 1927 to 1930, inclusive. The temperature records were obtained by burying recording thermometers in the loads of fruit.

In the first 10 shipments the temperature in the top of the load averaged for the trip about 12° F. higher, and in the last 5 shipments about 13.5° higher than that in the bottom of the load. During the first 36 hours after loading, the temperature in the top of the load averaged about 18° higher than that in the bottom of the load in the first group of shipments and about 20° higher in the second group. The fruit in the top of the load required about eight times as long as that in the bottom of the load to reach a temperature of 59° and about five times as long to reach a temperature of 50°.

Test shipments of peaches were forwarded in each of the 15 cars mentioned above. It was found that the temperature in the top of the car had about two and a half times as great growth value for brown rot as did the temperature in the bottom of the car,[11] but the

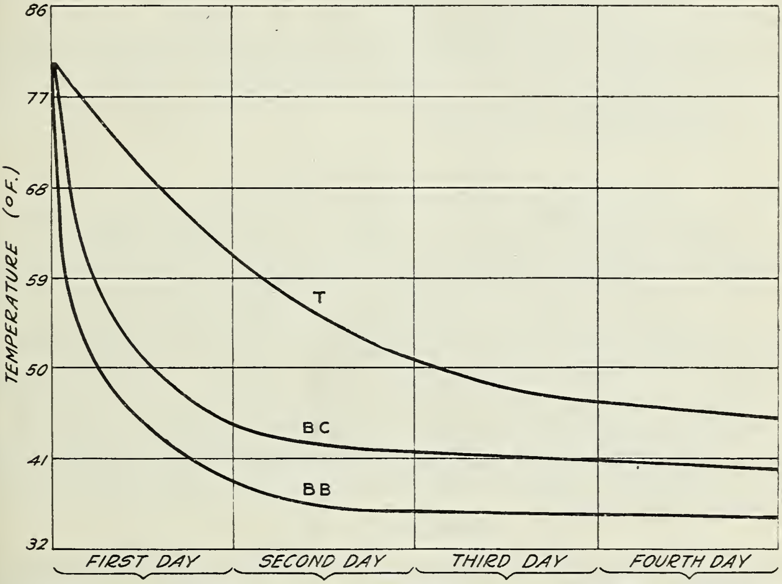

FIGURE 6.—Average of temperature records in standard refrigerator cars for 5 shipments of peaches, 1927 to 1930: T, Average of records taken at top bunker and top doorway; BC, at bottom center, BB, at bottom bunker. The cars were loaded four crates high

contrast in occurrence of brown rot was much greater than is indicated by this ratio. Peaches that were exposed to brown-rot infection 1 to 6 hours before loading developed about 50 times as many rots when located in the top of the car as when located in the bottom of the car. When exposures to brown rot were made 14 hours or more before loading there was much less difference between the top and the bottom of the car, the final results showing the combined effect of temperature conditions before and after loading.

The effect of car temperature upon Rhizopus rot was much greater than that upon brown rot; in fact, unless Rhizopus rot had made a considerable start before the peaches were loaded, it was usually unable to make an evident growth during the period of shipment under the temperature conditions that prevailed in the bottom of the cars.

[11] BROOKS, C., and COOLEY, J. S. Op. cit. (See footnote 7.)

With Georgia peaches loaded four crates high the rots are likely to make a greater development in the top of the refrigerator car in the first 24 hours than they make in the bottom of the car in a whole shipping period of 3½ to 4½ days. One day's delay at the usual summer temperatures before loading may be responsible for the development of more rot than is the whole period in transit.

PREVENTING SPOILAGE IN TOP OF CAR

PRECOOLING

The excessive spoilage in the top of the load can readily be prevented by precooling. Where cold-storage space is available and the value of the product will justify the expense, it is highly desirable that the fruit be cooled before it is loaded. Cooling to a temperature of 50° F. will practically eliminate Rhizopus as a factor in spoilage and will slow down the action of brown rot to a rate lower than usually prevails in the top of a refrigerator car two days after loading. Cooling to lower temperatures has proportionately greater effect with brown rot, especially in long-distance shipments.

USING CAR BLOWERS

Cooling of the top of a load of warm fruit before shipment can be hastened by using car blowers.[12] Various types of blowers have been devised to reverse and intensify the air movement in the car by forcing the cold air up through the bunkers and out over the top of the load. These car precoolers have a decidedly beneficial effect while they are being operated; they hasten the cooling at the top of the load without causing much delay in the cooling at the bottom. However, when they are removed as the car starts for market there is a decided lag in the cooling at the top of the load, due to the reversal of the air movement. The effectiveness of their use depends greatly upon how long they are operated. Four to six hours of operation are usually required for satisfactory results.

ADDING SALT TO ICE

Applying salt to the ice in the bunkers makes the whole load cool more rapidly and is of decided assistance in checking the rots and slowing down the softening of the fruit. Salting has an advantage over the use of car blowers, since it causes no delay in forwarding the shipment; but its use must be limited because of the danger of freezing the fruit at the bottom of the car near the bunker. The treatment usually consists of adding salt to the amount of 2 to 4 per cent of the weight of ice in the bunkers.

USING SOLID CARBON DIOXIDE

The results of experimental shipments [13] indicate that the spoilage in the top of the car can be greatly reduced by a limited use of solid carbon dioxide in addition to the usual icing. The refrigerating effect

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[12] GALLOWAY, A. G. A PORTABLE PRECOOLING APPARATUS. U. S. Dept. Agr., Bur. Plant Indus. [Mimeographed.] July 15, 1929. (Also in Ice and Refrigeration 81:19–22. 1931.)

[13] BROOKS, C. THE EFFECT OF SOLID CARBON DIOXIDE UPON TRANSPORTATION DISEASES. Ice and Rerigeration 81:48–50. 1931.

BROOKS, C., MILLER, E. V., BRATLEY, C. O., COOLEY, J. S., MOOK, P. V., and JOHNSON, H. B. EFFECT OF SOLID AND GASEOUS CARBON DIOXIDE UPON TRANSIT DISEASES OF CERTAIN FRUITS AND VEGETABLES. U. S. Dept. Agr. Tech. Bul. 318. 1932.

of this material may be almost entirely offset by a slower melting of the ice in the bunkers, but the solid carbon dioxide is gradually converted into carbon dioxide gas, which has a decided effect in checking both the development of rots and the softening of the fruit. By using carbon dioxide both of these spoilage factors can be brought under almost complete control within half an hour after the car is closed, a speed of action that can hardly be secured by precooling, much less by salting or the use of car blowers. The objectionable feature of using solid carbon dioxide is the fact that too great or too long exposure to carbon dioxide gas may reduce the natural aroma and flavor of the fruit. Peaches and apricots are particularly susceptible to such injury; plums and cherries are much more resistant.

SUMMARY

The inspection certificates of the Bureau of Agricultural Economics, United States Department of Agriculture, for the years 1922 to 1928, inclusive, although covering less than 3 per cent of the total car-lot shipments of peaches, show that on this 3 per cent alone there was a development of decay in transit due to brown rot and Rhizopus rot that at average market prices meant an annual loss of about $200,000. No records for the remaining 97 per cent of the shipments are available.

The losses from brown rot were greatest in rainy seasons.

With cherries and plums, as well as with peaches, sound fruit from unsprayed trees developed approximately four times as much brown rot in transit as sound fruit from sprayed trees.

Rhizopus rot has little chance to start on fruit with unbroken skins, and the development of brown rot is greatly favored by all forms of injury.

In cars loaded with peaches in crates the inspection reports show 7.8 times as much brown rot and 15.6 times as much Rhizopus rot at destination in the fourth or top layer as in the first or bottom layer, and in cars loaded with baskets 4.8 times as much brown rot and 5.4 times as much Rhizopus rot in the third or top layer as in the first or bottom layer.

Test shipments with peaches in crates showed that in a trip lasting three and one-half to four and one-half days the temperature in the top of the load averaged about 12.5° F. higher than that in the bottom of the load. The fruit in the top of the load was about eight times as long in reaching a temperature of 59° and about five times as long in reaching a temperature of 50° as that in the bottom of the load.

Four methods of decreasing the excessive spoilage in the top of the car are described: (1) Precooling the fruit; (2) using a car blower to precool the load; (3) adding salt to the ice; and (4) using limited quantities of solid carbon dioxide in addition to the regular icing.

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U. S. GOVERNMENT PRINTING OFFICE: 1933

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